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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

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THIS ISSUE

Temperature Control

A Discussion of the Maintenance of the Most Effective Lubricating Viscosity

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Temperature Control

A Discussion of the Maintenance of the Most Effective Lubricating Viscosity

IN the lubrication of certain types of machinery, a comparatively wide range of operating temperatures will frequently prevail. These may or may not be internal; it will all depend upon the construction of the machine and the principles of operation involved. The automotive and Diesel engines are typical instances of where high internal temperatures must be met by lubricating oils. Conversely, the handling of wire rope is illustrative of a condition where low external temperatures may frequently be encountered.

A considerable load will be imposed upon any lubricant wherever it may be called upon to function over a wide temperature range, for temperature has a direct bearing upon the operating viscosity, or the ability of an oil to maintain a lubricating film of sufficient body to prevent metal-to-metal contact between the moving or wearing elements. In view of this fact, where high internal temperatures may be encountered, cooling of such parts as the cylinder walls of the internal combustion engine, or the pistons of large Diesel engines, will be customary, and essential, to proper operation.

METHODS OF COOLING

The most common cooling media involved in connection with the internal combustion engine or the average industrial bearing will be water. On the other hand, air-cooling has been employed to some extent on certain automotive engines, and especially on the radial type of air-craft engine. It will be of further interest to note that oil has also been used for cooling purposes in connection with the pistons of certain Diesel engines.

Water as a Cooling Medium

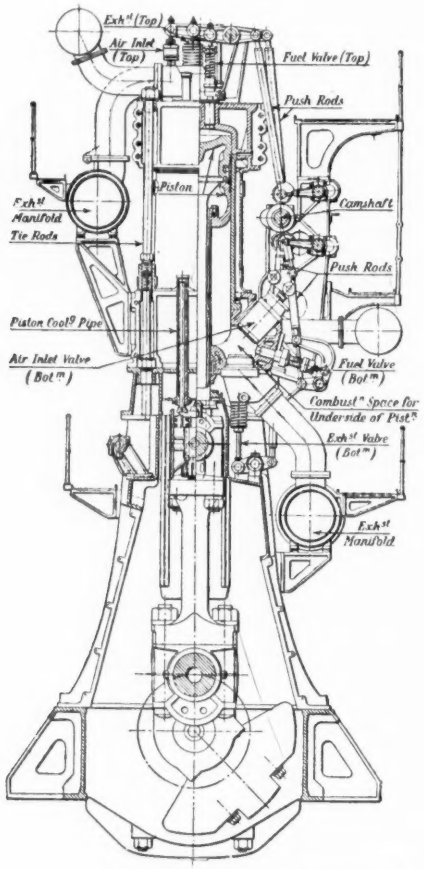
There are certain distinct advantages attached to water for cooling of industrial and automotive equipment. In brief:

1. It is obtainable in virtually any quantity in most localities.
2. It is cheap and can be economically handled.
3. Frequently no precautions are necessary in regard to storage or the disposition of waste.
4. It has a high cooling effect by reason of its high specific heat or, in other words, ability to take up heat.

Water, on the other hand, has a distinct disadvantage in that should leaks develop between the cooling and lubricating systems, undesirable contamination of the lubricant would result. The extent to which this might be detrimental to subsequent operation would depend upon the degree of refinement of the oil, and the design of the machine.

In the steam turbine, for example, where the highest grade oils are used, water contamination would be a very serious matter. Steam turbine oils must be specially refined with a view to showing the least possible tendency to emulsify with water, for emulsification and subsequent agitation in the presence of air is

the forerunner of sludge formation. Sludge is non-lubricating, and frequently of a sufficiently viscous and sticky nature as to lead to obstruction of oil lines, bearing grooves or other parts of the lubricating system. Obviously, this would impair lubrication, due to possible reduction in circulation of the oil.



Courtesy of Burmeister & Wain A/S.

Fig. 1.—Section through a double-acting four-stroke cycle Diesel engine. Each cylinder of this engine is capable of developing over 1100 shaft horse power at 125 R.P.M. An interesting feature is the oil-cooled piston and rod. The rod is fitted with a cast iron liner. Between this latter and the steel piston rod is a ring-shaped space through which the oil is carried to the piston. Oil is discharged through the middle of the bored out piston rod.

It is important to remember that reduction in the rate of oil circulation will also decrease the cooling ability of the oil. This is, of course, only a partial function of the lubricant, but if circulation is maintained at a sufficient rate it will materially aid in reducing bearing temperatures, particularly at the wearing surfaces where over-heating would be most detrimental.

Air Cooling

The degree of success which can be attained by air cooling will depend upon the provisions for complete circulation of air to the heated parts, to bring about adequate heat transfer.

As a general rule, air cooling as an adjunct to lubrication is most practicable in connection with moving machinery, such as the airplane or automobile engine. Here a natural draft is developed by the passage of the engines through the air. On the other hand, it is, of course, practicable to develop artificial draft by means of fans or blowers. Unless this draft is led directly to the parts to be cooled, however, much of its intensity and cooling value will be dissipated to the surrounding atmosphere.

The airplane engine, by virtue of the comparatively high rate of speed at which it travels through the air, has been a most ideal subject for the utilization of air cooling. The radial engine has received the most attention in this regard, due to the arrangement of its cylinders and the fact that each cylinder can be surrounded with an arrangement of fins for air distribution to the exterior walls. Furthermore, inasmuch as all are located in the same plane, air will be distributed equally, and there will be no possibility of any cylinders receiving heated air from the others.

Oil Cooling of Diesel Engine Pistons

As an adjunct to lubrication, the use of oil as a cooling medium has received the most attention in the Diesel engine industry. For this purpose, mineral oils possess the most satisfactory characteristics, in that they will show the least tendency to gum or develop heat resisting deposits, especially when subjected to wide temperature variations. Mineral oils, however, have a considerably lower cooling ability than water, due to their low specific heat.

On the other hand, they possess the distinct advantage, in that, should leakage develop, the quality of the lubricant will normally not be materially lowered, especially if the oil which is used for cooling is of a sufficient degree of purity.

The above is of material importance in the operation of the modern Diesel engine. Construction of virtually all the large high speed engines requires cooling of the pistons. This can, of course, be accomplished by either water or oil. The use of the former has already been mentioned. Oil, in turn, is being given equal consideration, for it is added insurance that lubrication will not be impaired due to possible development of non-lubricating sludges. Oil as a cooling medium, however, is limited by the design of the piston. This must be such as to insure continuous turbulence of flow within the cooling medium in order to prevent, as far as possible, the formation of heat resisting films along the walls. Should such films develop, carbon deposits may be the ultimate result.

especially at the more highly heated parts of the piston.

In Heat Exchanger Service

Mineral oil has also been used as a cooling medium in connection with heat exchanger types of lubricating oil coolers. Such equipment is adaptable to steam turbine service; for example, where a considerable volume of oil must be continuously cooled. Here again, mineral oil, even though it may not possess as great a cooling ability as water, will serve to protect lubrication more effectively, should leaks develop within the cooler.

HANDLING OF THE COOLING MEDIA

With the exception of instances where water can be allowed to flow by gravity through a cooler, or where it can be piped directly from city water mains, some means of pumping must be resorted to whether oil or water is employed.

A number of types of pumps can be employed for this purpose, depending upon the size of the installation and the volume of coolant to be circulated.

Under general conditions of industrial plant or engine operation, the gear, rotary or centrifugal pump is used. The reciprocating piston or plunger pump is, of course, also adaptable, but in view of the fact that it will normally require steam for its operation it is but little use in connection with oil cooling.

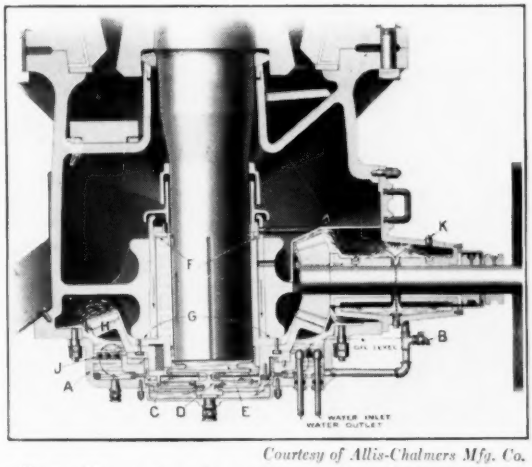
Circulating pumps can be driven either directly by the machine which they are to serve, by an independent electric motor or some other means of power transmission. In the automotive engine, it is customary to use a gear pump, driven by belt or chain connection from the main shaft. Where industrial bearings are involved, however, or where a more considerable volume of cooling media must be handled, independent means of drive is frequently adopted.

Pump Operation

The principle of rotary pumping such as is embodied in the gear, screw type or centrifugal pump is distinctive in that it involves no valves, springs or other small parts to wear out or become inoperative. Furthermore, there are normally no internal parts that require lubrication. In other words, where a cooling water pump, for example, may be installed externally, the only parts to be lubricated will be the bearings. With an internally installed gear pump, on the other hand, lubrication is brought about from the machine itself. It will be interesting to study in more detail the essential principles of the above mentioned pumps.

Centrifugal Pumps

The centrifugal pump involves essentially one or more rotors or impellers, revolving in a fixed plane within a suitable air-tight casing. Water or oil, as the case may be, is received at the hub or center of the impeller, pressure being



Courtesy of Allis-Chalmers Mfg. Co.

Fig. 2—Oiling system of a gyratory crusher. "A" is the bottom plate and oil reservoir, "C" the centrifugal pump, "D" the diffuser. From the latter oil passes to space "E" inside the eccentric below the shaft. Thence it is forced up between eccentric and shaft overflowing the top through holes "F". In returning it flows by gravity through clearance space "G", between the main bearing and eccentric flange. Centrifugal force throws ample oil over the gears to give adequate lubrication. "J" indicates the cooling coils.

acquired as it is impelled outward to the circumference by means of suitable blades. Dependent on the type, fixed discharge valves are used similar to stationary nozzles, or a suitably spiral casing is employed for such purposes. Volute pumps are of this latter type.

In order for a centrifugal pump to attain maximum efficiency, it must operate free from air leaks, not only in the suction but also in the pump. The discharge pump must be of such a diameter as to insure the delivery of the liquid with a minimum of friction, the operating speed must be commensurate with the pumping head and there should be a minimum of sharp bends and elbows in any piping involved.

The centrifugal pump is a valuable piece of machinery where variable pressure and volume conditions are to be met.

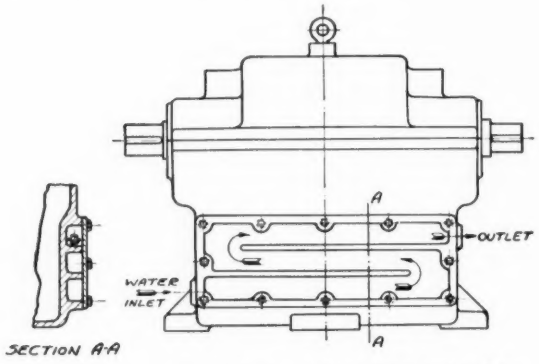
Rotary Pumps

Pumps with two rotating elements are commonly known as rotary devices, whether these elements are gears, screws, pistons, impellers or cycloids. Essentially, the principle is that of the geared pump, the matter of teeth or lobes being the criterion.

The most common type of such a pump is the geared device as used in connection with the automotive engine. While it serves chiefly as a lubricating pump it is important to remember

that the volume of oil which it delivers to the wearing elements also insures a certain amount of cooling.

This same result is obtained in the lubrication of certain types of steam turbines using a pump of similar construction.



Courtesy of Moore Steam Turbine Corp.

Fig. 3—Showing a method of water-cooling the oil adjacent to reduction gears. Note flow of water, as well as sectional detail of the cooling element.

Pump Lubrication

As stated, where a pump is built into the machine which it is to serve, it will normally be designed for the handling of oil, the function of which is both to serve as a lubricant and a coolant. At the same time, this oil serves to lubricate the pumping elements.

Where either a centrifugal or rotary type of pump is designed for the handling of cooling water, it will be installed adjacent to the main machinery, but usually driven directly therefrom through gear, chain or belt connection.

In pumps of this type it will, of course, be essential to lubricate the bearings, for the pumps cannot be expected to function effectively as an aid to lubrication if they are not, in turn, properly lubricated.

Bearing Design

While pumps of this character will involve essentially the lubrication of bearings, these latter may be of a number of designs, and involve specific problems according to the operating conditions. As a result, they require serious consideration and cannot be passed over as mere instances of ring oilers, ball bearings, etc., or plain babbitted bearings served by oil or grease cups.

Ring and Collar Oilers

For general all-round service on horizontal pumps the ring or collar oiler is preferred by many builders due to the comparative simplicity, cleanliness, the extent to which automatic lubrication is developed, the small amount of attention required, the economy, and the uniformity and regularity of oil distribution.

In construction such an oiler comprises a bearing housing which is built with a reservoir and a slot of sufficient width and depth to permit one or more rings or collars suspended from the shaft to revolve therein. As a result, with the revolution of the shaft, these elements, being subjected to rotation, will carry a flood of oil to the top of the shaft from whence it is able to flow into the bearing oil grooves and clearance space to be ultimately distributed to the entire wearing surface as shown in Fig. 4.

As a rule, the oil after being passed through the bearing will flow out to the end or ends of the shaft through a suitable return chamber which is part of the bearing housing, back to the oil reservoir below. Ring oilers are not usually recommended for bearings below two inches in diameter, especially where high speeds are involved, due to occurrence of excessive slippage of the rings, and the possibility of foaming arising in the oil where reservoir capacities are limited.

Handling of oil in this manner is today regarded by many as the simplest adaptation of the most efficient method of lubrication whereby the bearings are flooded with a considerable excess of oil over the amount that would theoretically be necessary to furnish the requisite oil film. By flooding the bearing with oil the latter serves not only as a lubricant, but also as a cooling medium to carry away part of the frictional heat developed, thereby reducing the temperature of operation. If the oil reservoir in the base of the bearing has been properly designed and is of sufficient capacity, this overheated oil will have ample opportunity to become sufficiently cooled after each circulation by contact with the reservoir walls, particularly if the radiation of the latter is not interfered with.

Lubricating systems of this nature possess natural advantages in that the flood of oil which is constantly passing through the bearings tends to wash out any grit, dirt, dust or metallic particles that may have gained entry, as a result, reducing wear to a minimum. On account of this washing action of the oil, however, the reservoir will gradually tend to accumulate a certain amount of sedimentary deposits. Therefore it should be flushed out and cleaned at intervals, the old oil being replaced with new or purified oil. This is especially important when such a system is new and core sand, etc., may be present. In such cases several frequent changes are recommended.

It is evident that flood lubrication works on the opposite theory to that of supplying a bearing with just sufficient oil to furnish the neces-

sary lubricating film. In fact, today in many types of machinery, flood lubrication is the only method allowed by the builder. On the other hand, there are many arguments in favor of regulated lubrication such as embodied by the drip cup or automatic force-feed lubricator.

Anti-friction Bearings

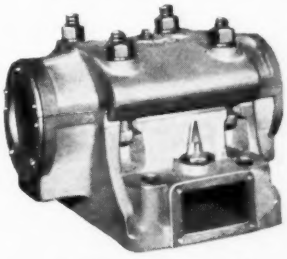
Ball or roller bearings are, however, preferred on certain of such types of pumps. They are advantageous in that they supplant sliding motion with rolling motion, thereby reducing the resultant friction where properly lubricated.

Ball bearings involve point contact, whereas roller bearings involve line contact. In the lubrication of either type, however, one of the chief functions of the lubricant is to prevent corrosion of the highly polished surfaces. As a result, wherever possible, the housings should be oil-tight for thereby can we reduce the viscosity of the lubricant and in consequence the internal friction that will be developed during operation.

Where leakage is possible, however, a grade of light to medium grease should be used which will have just enough body to cause it to remain in the bearing housing. Lubricating attachments such as oil or grease cups are usually unnecessary on such bearings, it being customary to charge or fill the housing and raceways with the proper grade of lubricant, through a suitable opening or fitting which can be effectively sealed or plugged during subsequent operation to prevent the lubricant from flowing out.

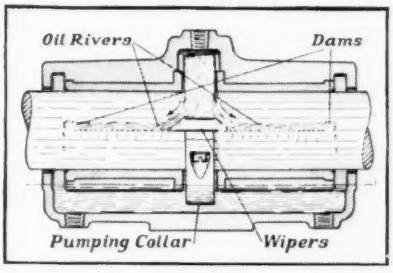
In general, one charge of oil to a roller or ball bearing equipped with an oil-tight housing should last for a period of several months. Where grease is required, however, it should be renewed according to the extent of seal which is maintained.

All rotary pumps, however, will not require or be equipped with ring oilers or anti-friction bearings. In certain cases, grease cups or sight feed oiling devices may be regarded as suitable by the builders, especially where operation is to be more or less intermittent. For such service a medium bodied engine oil or a plastic grade of cup grease will in general be found to serve the purpose in a satisfactory manner.



Courtesy of The Hill Clutch Machine & Foundry Company

Fig. 4—Illustrating the Cleveland type oil film bearing designed for high-speed and high temperature service. This is a non-water-jacketed type of bearing. Line sketch illustrates the principles involved in bearing construction, whereby a flood of oil is positively delivered along the entire bearing by the rotating collar which is attached to the shaft. Wipers deflect this oil into suitable channels to insure maintenance of the oil film. There are no oil grooves in this bearing. Heated oil is returned to the reservoir where it is cooled prior to redistribution.



RELATION OF VISCOSITY TO TEMPERATURE

In view of the fact that the viscosity or body of any oil is directly affected by temperature, this characteristic must be thoroughly understood wherever oils are to be selected to meet varying operating temperatures.

It is a characteristic of most liquids to become thinner or more fluid when subjected to an increase in temperature. For the information of the layman, in the petroleum industry this is termed reduction in viscosity.

It will be of further advantage to state that viscosity is regarded as a measure of the relative fluidity of an oil at some definite temperature of observation. In brief, it is that inherent property by virtue of which the flow of certain liquids will be retarded. It is possessed by all lubricating oils to a varying degree, depending on their source, range of distillation, and extent of refining or blending.

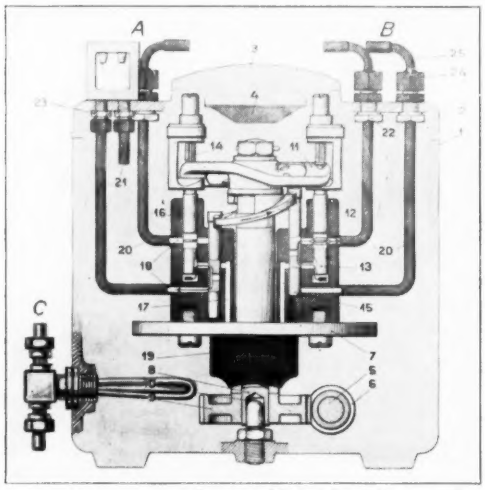
As a result, wherever abnormally high or low temperatures must be encountered, the viscosity of the lubricant must be given the most careful consideration. Simply because the lubricant may be cooled or preheated prior to application or circulation to the wearing elements is no criterion that its viscosity in service will be able to maintain an adequate lubricating film. Attention must be given to the operating temperatures and the original oil selected with this in view.

Modern Engine Conditions Require Higher Viscosity

It is perfectly evident that our modern conditions of higher Diesel and automotive engine temperatures will lead to an increase in the degree of fluidity of the oil which is used for lubrication. Especially will this be true in warm weather, when the amount of external cooling will be appreciably lower than in cold weather, or under lower atmospheric temperature conditions.

This will call for the utmost care in the selec-

tion of the proper grade of lubricating oil for warm weather operation. Haphazard choice without adequate knowledge of the approximate "operating viscosity" of the proposed oil may be the forerunner of too great a variation in the fluidity of the oil in service, with often-



Courtesy of Robert Bosch Company, Inc.

Fig. 5—Sectional view of the Bosch lubricator pump, showing heating element at "C". The design of this lubricator is of interest, in view of the fact that it lends itself as readily to the handling of grease as oil under constant flow. The further provision for heating is extremely advantageous where heavier lubricants are to be pumped under comparatively low temperatures.

times ineffectual lubrication of certain of the wearing parts. The ultimate occurrence of scored or burned out bearings, of abnormal wear on cylinder walls, and an excess of oil pumping past the piston rings, will all lead to increased cost of maintenance and a natural decrease in power output or engine efficiency.

The Operator Must Be Informed

In view of the importance of the viscosity characteristics, and the attention which should be given to it by the operator when selecting such oil, he should be informed both as to the method of test and the range of limitations for the several accepted grades of oils. In other words, he should know the approximate range of viscosity involved when he buys a grade of "heavy" oil, for example, regardless of whom it is manufactured by. Furthermore, he should know what the oil industry means by stating that a certain "heavy" oil has a viscosity of, say, 500 seconds Saybolt at 100 degrees Fahr.

In this way any attempt to "put over" improperly refined oils which may be way out of line in regard to the "operating viscosity" requirements of any particular engine or machine can be detected.

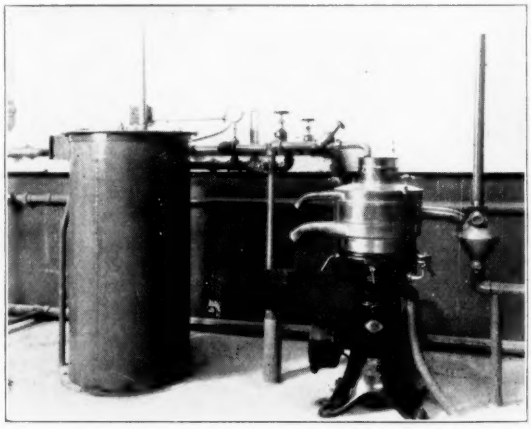
A Typical Example

For example, say a motorist should call for a quart of motor oil heavy of "X" brand. In some cases the colors of certain motor oils are so nearly alike as to be deceptive. So the dealer in question has had a chance to stock up with a grade of "Y" oil at a low price and of a comparatively low viscosity. This product he foists on the unsuspecting customer who called for "X" motor oil.

But if the latter is posted on viscosity he will usually detect a difference the moment "Y" oil starts to pour into his crankcase. He should then call the dealer, stop the addition of any more oil, and immediately ask for an approximate viscosity comparison with a standard sealed sample bottle of motor oil heavy of "X" brand.

This is an easy test to make, by simply filling a bottle of approximately the same capacity with the proposed oil, corking the latter, and inverting both simultaneously, watching the rise of bubbles in each. The more rapidly these latter rise the lower the viscosity. Hence, if the bubble in the sample of suspected oil rises more rapidly than that in the standard sealed sample of motor oil heavy of "X" brand, the viscosity of the former is probably too low and usage of such an oil might subsequently cause trouble due to insufficient lubrication.

Such a comparison test affords an ideal opportunity for checking up on any dealer who may be imposing on both the motoring public and the reputable oil company for whose product he is attempting to sell inferior substitutes.



Courtesy of De Laval Separator Co.

Fig. 6—In the purification of transformer oils, it is also beneficial to install means for heating. The relative size and location of the electric heating element shown at the left, in contrast with the oil purifier, will be of interest.

Meaning of Viscosity

As a result the operator should know that when the statement is made that an oil has a viscosity of let us say 500 seconds Saybolt at 100 degrees Fahr., this means that the body or relative fluidity of the oil in question is such

that, at a uniform temperature of 100 degrees Fahr., it will take 60 cubic centimeters of this oil 500 seconds to flow through the orifice of the standard Saybolt viscosimeter.

In other words, viscosity is measured by observing the time required for a predetermined quantity of oil to flow through an orifice of standard size under standard temperature conditions. The Saybolt universal viscosimeter has been adopted for this purpose by the American Society for Testing Materials.

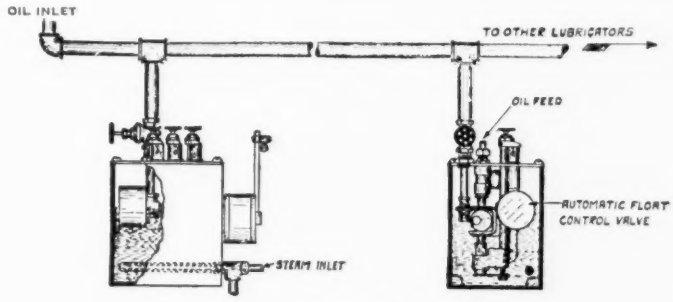
Temperature of Test

It is evident that any temperature could be selected for such a test. The petroleum industry, however, usually regards 100 degrees Fahr. as standard when dealing with motor oils of normal fluidity; that is, products up to about 900 seconds viscosity. For heavier products, such as gear lubricants, and certain motor-bus or airplane engine oils, 210 degrees Fahr. is the usual standard temperature. The advantage of raising the temperature of test with such products is to decrease the time element involved and expedite the actual procedure of testing.

Value of the Viscosity-Temperature Chart

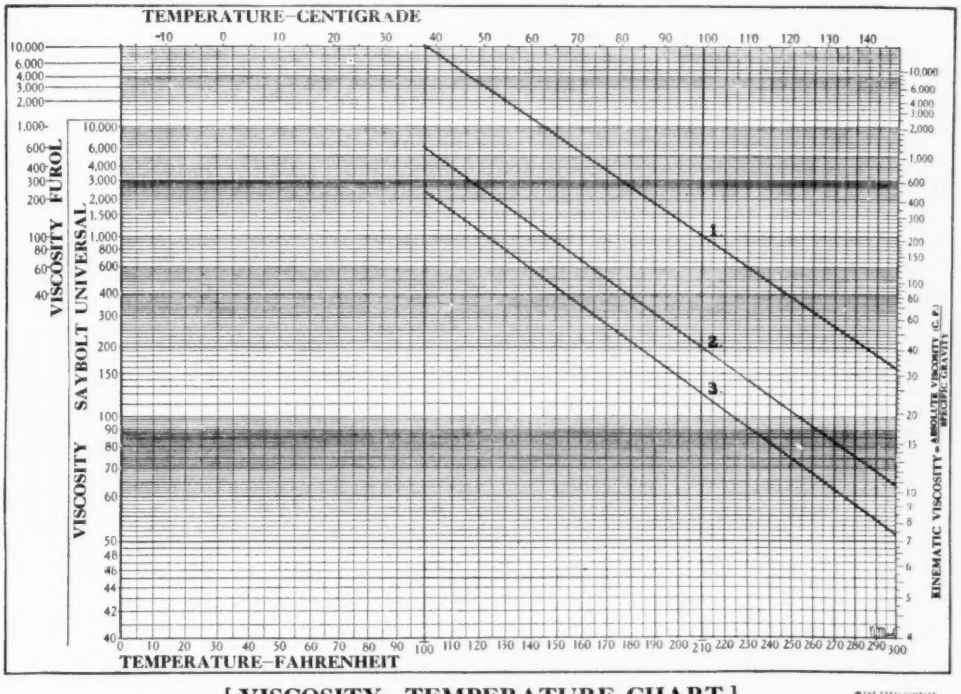
In connection with this matter of viscosity, it will be of interest to study the viscosity-temperature conversion chart shown in this article and to note the curves for typical grades of lubricants refined to meet the requirements of average operation.

With such a chart it is possible to estimate very closely the approximate operating viscosity of any particular grade of oil up to 300 degrees Fahr., or to note what the viscosity would probably be at atmospheric tem-



Courtesy of S. F. Bowser & Co., Inc.

Fig. 7—Illustration of method of installing force feed oilers in series, in order to enable automatic maintenance of oil supply. Note also means for steam heating in case low temperature operation is necessary.

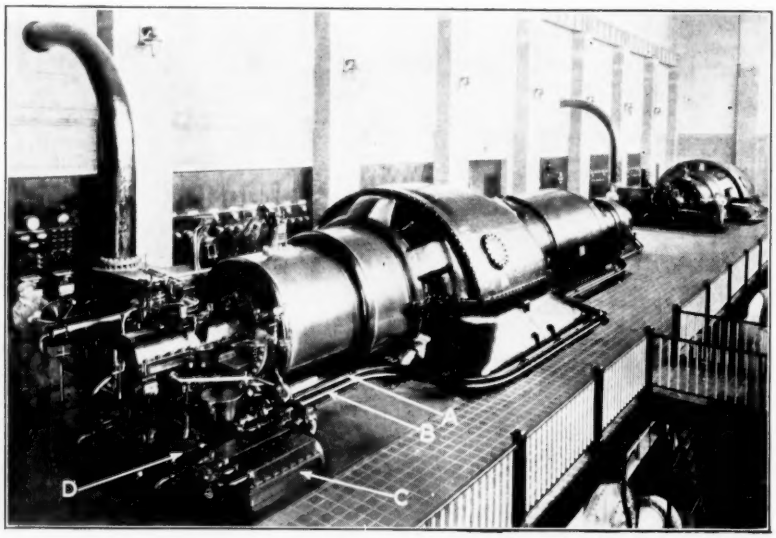


[VISCOSITY—TEMPERATURE CHART]

Fig. 8—The above chart shows the viscosity-temperature curves for three representative mineral lubricants adaptable to moderately high temperature service. The points of observed viscosity are 100 degrees and 210 degrees Fahr. in each case. As an example of how to use this chart in the determination of the approximate "operating viscosity" of, say oil "1" at 300 degrees Fahr. note that the extension of this curve to 300 degrees Fahr. on the horizontal scale intersects the 160 seconds Saybolt viscosity line on the vertical scale. In other words, a condition of bearing operation which would require an oil of from 150 to 180 seconds Saybolt viscosity at normal room temperatures could be adequately taken care of by oil "1" at an operating temperature of 300 degrees Fahr.

perature down to zero. Of course, this latter only applies to oils of zero pour test.

It is invaluable to the operator to be able to study lubricating oils from this point of view, for it will be bound to lead to a more intelligent selection of an oil which will be capable of assuring effective lubrication by virtue of its proper "operating viscosity" at the mean operating temperature of the machinery involved.



Courtesy of Allis-Chalmers Mfg. Co.

Fig 9—A steam turbine installation showing relative size of oil piping, pump and cooler. "A" indicates the main oil supply line to bearings; "B" the oil return pipe; "C" the oil cooler and "D" the Auxiliary oil pump.

In addition, it is important to state that the operator should guard against any hasty impression that oils of lighter color will have less body than comparative products which may be darker or more opaque. The viscosity test is the sole criterion and should be used as the only comparison when body is in question.

Color has absolutely no bearing upon viscosity, though it is a very vital factor as an indicator of lubricating ability, for it is a direct guide as to the probable carbon residue content of any oil.

Maintenance of Proper Viscosity

In connection with this matter of viscosity it will be of further interest to discuss the manner in which this is maintained in the modern automotive engine. From the first, water-cooling was almost immediately resorted to. For years, however, but little attention was given to control of the cooling water temperature. Primarily this was due to the fact that it was little realized how much these temperatures would affect engine operation, proper lubrication and crankcase dilution.

Research has indicated, however, that if the temperature of the cooling water is not maintained sufficiently high, the temperatures of the cylinder head and walls may drop to a sufficient degree to permit incomplete vaporization of the gasoline and incomplete combustion of the fuel-air mixture. In other words, a certain amount of the fuel will tend to remain in liquid state, to be absorbed by the lubricating oil film on the cylinder walls during the down-stroke of the piston, to ultimately find its way into the crankcase and dilute the oil therein.

It is for this reason that most of the modern automotive engines today are provided with thermostatic means for controlling the temperature of the cooling water and keeping this at a sufficiently high degree.

The thermostat prevents free circulation of the cooling water through the cylinder cooling jackets until the temperature of the walls has reached the desired degree for which the thermostat is set.

REQUIREMENTS OF A TURBINE OIL

It has been noted that, in the steam turbine, the oil serves two primary purposes, one to lubricate or reduce friction to a minimum, the other to carry away heat. In order for an oil to lubricate it must be of the proper viscosity, for solid friction must be absolutely supplanted by fluid friction, this latter in turn being as low as possible. The viscosity or body of the oil is the controlling element, contingent, of course, upon the clearance spaces which exist between the shaft and bearings.

As a general rule, the higher the clearances and the more accurately these are expanded by chamfering of the bearing edges at the point of entry of the oil, the more easily will the shaft be able to draw a suitable film of oil into this space. On the other hand, if the viscosity is too low the oil may not be able to withstand the bearing pressures involved, or if it is too high there may be altogether too much internal friction brought about. Either of these conditions will lead to an appreciable increase in operating temperatures.

Bearing Cooling Essential

Therefore, in turn, the oil must be capable of acting as a cooling medium, for a certain amount of heat will be developed, regardless of how perfectly the operating conditions are adapted to effective lubrication.

Such cooling is aided by pumping a considerable volume of oil through the bearings. This has the effect of both maintaining lubrication as well as lower temperatures, and decreased power consumption at the bearing. Of course, if cooling is not brought about, the viscosity of the oil will in all probability be so reduced that the oil film will not be able to withstand the pressure of operation; in other words, it will break down and metal-to-metal contact will occur.

No definite data have as yet been derived which can be safely said to actually aid in the selection of oils of the proper viscosity. It is more or less of a problem of "cut and try," according to the operating conditions involved. As a rule, however, there should be little difficulty inasmuch as turbine builders and oil refiners in company with the technical experts of a number of public utilities have cooperated in the development of considerable research data in this regard.

Where reduction gears are involved, whenever the same oil is to be used for lubrication of both gears and bearings, a certain increase in viscosity will be necessary in order to insure effective lubrication of the gears. Here duty will be considerably heavier, imposing pressures on the lubricating film in excess of those involved in the bearings.

On the other hand, this lubricant must not be so heavy as to lead to the development of abnormal internal friction within itself when in service in the bearings. An oil with a steep viscosity curve has been found to be the most adaptable for such service; that is, it should adhere to its original viscosity as nearly as possible when in service in the gear case; yet be capable of decreasing so rapidly in viscosity with normal increases in temperature that when fed to the bearings at temperatures in the neighborhood of 140 degrees Fahr. it will be reduced to approximately the viscosity of the lighter oil which would normally be used for bearing lubrication alone.

Wherever an oil is to be used for the lubrication of both reduction gears and bearings it should seldom have a viscosity below 300 seconds Saybolt at 100 degrees Fahr. In general, an oil of this viscosity will function with perfect satisfaction in the average stationary, reduction geared turbine. In some classes of service, on the other hand, the size of the gears may be considerably larger, with corresponding increases in tooth pressures. Therefore, it will often be found advisable, in such cases, to use an oil of approximately 500 seconds Saybolt viscosity at 100 degrees Fahr., or even higher in abnormal cases.

An important point to remember, however, in the lubrication of reduction geared turbines is that we should never use an oil of any higher viscosity than absolutely necessary, due to the fact that the heavier the oil the less readily will it separate from water. Furthermore, unless bearing temperatures are above the average, there will be a tendency for marked increase in

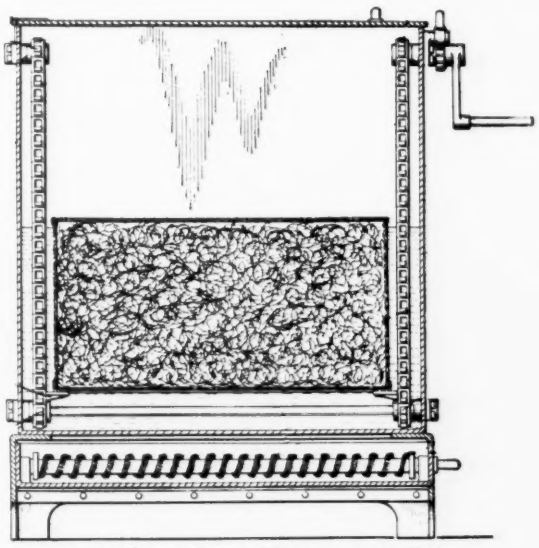


Fig. 10—Electrically heated Waste Saturating Tank.

internal friction due to the oil being too heavy for the service involved. This, of course, would lead to a certain increase in temperature, which would automatically tend to reduce the viscosity to a certain extent, with the result that ultimately an equilibrium temperature would be reached. We must, however, not overlook the fact that increase in temperatures may tend to increase the sludge formation.

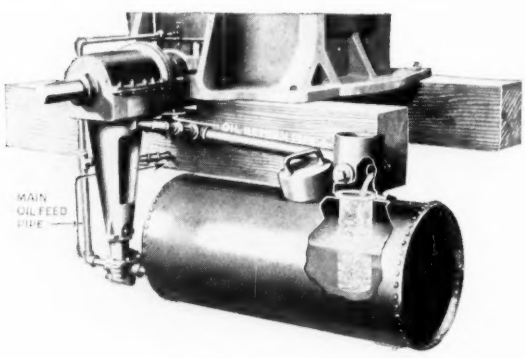
Actually, therefore, the operator must watch his turbine temperatures carefully. If they tend to run above 140 degrees Fahr., unless there are certain mechanical conditions involved to which this can be directly attributed, he would be safe in investigating the suitability of his oil or the extent to which foreign matter and sludge are being removed.

AIRCRAFT ENGINE COOLING

In the operation of an aircraft engine it is important to remember that it is virtually impossible to shut down for the purpose of cooling, for any length of time. Landing must be made if this is necessary. If forced down serious consequences may result.

It is therefore most essential to provide for adequate means of cooling and protection of lubrication while in the air, by either suitable water jacketing where a water-cooled vertical or Vee type engine is involved, or by an arrangement of fins on each cylinder in the air-cooled radial or rotary engine.

Effective lubrication of cylinder walls especially is directly contingent upon the extent to which they are cooled. Combustion temperatures are comparatively high and it is virtually impossible to prevent transfer of more or less heat to the lubricating film. It is practicable, however, to control the rate of heat transfer and the temperature of the cylinder walls, to thereby prevent dangerous reduction in the viscosity of the oil. In the beginning only cylinder walls and piston rings would be affected by the oil being too thin, but due to the fact that heat transfer occurs within the main body of the oil in the system, the bearings would very soon suffer likewise, even to the point of seizure.



Courtesy of Smith Engineering Works.

Fig. 11—Showing the gear type oil pump employed on the Telsmith primary breaker. Note the oil feed line, return pipe and strainer. This device affords full pressure lubrication to all gears and bearings of the crusher.

As stated, control of engine temperatures is maintained by air or water cooling. Where direct air cooling is provided for, as in the radial engine, weight per horse power is reduced and no intricate mechanisms are involved other than suitable fin construction on the cylinders. In the water-cooled engines, however, the circulating system, pump and radiator must be considered. All involve additional weight. In addition there is the weight of the water which must be carried. Water cooling is, of course, but an indirect form of air cooling, for the water after taking up heat from the engine is reduced in temperature by radiation prior to re-circulation.

Water-cooling, while involving more accessory engine equipment, may enable operation at somewhat higher engine speeds, although this advantage is claimed to be reduced by the most modern radials. Higher speeds would be advantageous in war time, or where racing planes are involved.

Water-cooling also permits of more ready control of engine temperatures and affords more reserve cooling. This is a distinct factor just as in the automotive engine, where complete combustion, fuel economy and maximum engine efficiency are under consideration.

Cold Weather Protection of The Automotive Engine

The Choice of Anti-Freezing Solutions

At this time, every year, a pertinent problem presents itself to motorists who must meet the rigors of cold weather driving, for they must think of engine and radiator protection. It is a difficult problem to many, for it involves the maintenance of adequate engine cooling and, at the same time, the least possibility of freezing of the cooling solution. Essentially, it is simply a matter of choice of this latter in sufficiently concentrated form to insure against freezing in any part of the system, however long the engine may remain idle. But what to use, or how much of it, is the question.

Freezing Must Be Prevented

Lack of consideration in this regard may result in freezing. Freezing alone might be comparatively negligible were it not for the subsequent effects which it might cause. For example, leakage might result in the radiator, the cylinder block might be cracked, or the water pump put out of commission. All on account of the extent to which water or any aqueous solution expands when it is allowed to freeze or solidify within a confined space.

HOW ANTI-FREEZING SOLUTIONS FUNCTION

The freezing point of the solution in the radiator of any motor vehicle must, therefore, be lowered below the probable lowest atmospheric temperature likely to be encountered in cold weather operation. To bring this about, the water must be mixed with a certain amount of alcohol, glycerin, ethylene glycol, alcohol plus glycerin, or dissolved salts.

The Properties Desired

Irrespective of the nature of the anti-freezing compound, the ideal solution should possess certain definite properties:

1. The ingredients used should be easily obtainable in operating localities.
2. The possibility of freezing should be negligible.
3. It should not be injurious to either the engine or the radiator through corrosion or electrolytic action, or to rubber hose connections.

How to Use This Data

Assuming that denatured alcohol is to be employed a typical example of how to use this table, where the lowest temperature anticipated is 10 degrees above zero Fahr., is as follows:

Provided that the radiator holds 3 gallons, 30% of this solution must be alcohol, with 70% of water. 30% of 3 gallons is 0.9 gallons, or approximately 7 pints. In round numbers, therefore, this quantity of alcohol should be added to enough water to make 3 gallons. In other words, 17 pints of water or 2 gallons plus 1 pint should be used.

Table Giving the Freezing Points and Specific Gravities of Certain Anti-Freezing Solutions

Solution	Percentage (by volume) in water, and freezing points.				
	10% °C °F	20% °C °F	30% °C °F	40% °C °F	50% °C °F
Denatured Alcohol... (90% by vol.).....	−3 +27 (0.988)	−7 +19 (0.978)	−12 +10 (0.968)	−19 −2 (0.957)	−28 −18 (0.943)
Wood Alcohol..... (97% by vol.).....	−5 +23 (0.987)	−12 +10 (0.975)	−19 −2 (0.963)	−29 −20 (0.952)	−40 −40 (0.937)
Distilled Glycerine... (95% by wt.).....	−2 +29 (1.029)	−6 +21 (1.057)	−11 +12 (1.085)	−18 0 (1.112)	−26 −15 (1.140)
Ethylene Glycol..... (95% by wt.).....	−3 +26 (1.016)	−9 +16 (1.031)	−16 +3 (1.045)	−24 −11 (1.058)	−35 −31 (1.070)

4. It should not lose its non-freezing and non-congealing properties after continued use.
5. The possibility of fire hazard should be minimum.
6. The boiling point of the solution should not differ materially from that of water.
7. The viscosity should be as constant as possible through the entire temperature range involved and the solution should remain perfectly fluid and not tend to stop up any small openings in the system.
8. It should be able to conduct heat away as rapidly as possible.

In this regard, the above table will be of decided interest. It shows the freezing points and specific gravities of certain anti-freezing solutions. It is based on data developed by the Bureau of Standards.

CHARACTERISTICS OF THE VARIOUS PRODUCTS

Alcohol-Water

Alcohol-water anti-freezing mixtures have probably been most commonly used by the motorist to date, owing to the fact that alcohol is easily obtainable at reasonable cost. The grade used may be either denatured or wood alcohol.

Alcohol solutions do not have any greater tendency to corrode the metallic parts of the system than water alone. On the other hand, wood alcohol will often contain free acetic acid. It is advisable as a result not to use wood alcohol unless it is definitely known to be acid free. The amount of alcohol used will affect the freezing point of the mixture, as is shown in the accompanying table.

Where using alcohol it is important to remember that this product will evaporate far more rapidly than water. As a result, a certain

amount must be added as make-up from time to time to keep the concentration of the mixture as desired. For this reason it is well to test the specific gravity of the alcohol mixture regularly with a hydrometer calibrated for temperature correction and check the reading with the above table.

Alcohol, however, lowers the boiling point of water to quite an extent if used in large amounts. Consequently, it may frequently happen that on a comparatively warm day when the engine is "idled" the solution will boil readily and abnormal evaporation will take place, thus raising the freezing point of the remaining mixture.

Glycerin and Ethylene Glycol

Glycerin and ethylene glycol, in contrast to alcohol, raise the boiling point of water slightly, and thus they neutralize to some extent the effects of alcohol in this regard.

Glycerin, however, is claimed to be somewhat more injurious to the rubber connections which are used between the radiator and engine. An ethylene glycol or a glycerin-water mixture does not evaporate as does an alcohol mixture, so the cost and amount of ingredients used in renewing the solution will depend only on the amount to be replaced due to leaks or mechanical losses.

Saline Solutions

Saline solutions can also be used as antifreezing mixtures. They are made by dissolving common table salt or more frequently calcium or magnesium chloride in water.

The principal advantages of such compounds is that they are cheap and non-volatile. On the other hand, their usage may give rise to troublesome consequences on account of their tendency to attack metallic parts of the system such as solder or aluminum, unless this can be counteracted by some other dissolved substance.

PROCEDURE IN CASE OF FREEZING

In event of freezing of the water or cooling solution at any time, either through carelessness or sudden abnormal temperature drop, never try to thaw it out by running the engine. If possible, the garage should be heated or the car should be towed to a warm place. If this is impracticable it may be possible to thaw out the system by applying towels or rags wrung out in boiling water to as much of the cooling area as possible, although observing every care that no water drips upon any part of the ignition system.

RADIATOR PROTECTION AND TEMPERATURE CONTROL

While it is most essential that the liquid in the cooling system be kept from freezing, it is also important that its temperature be controlled at least to some extent in order to enable the engine to operate at its best.

Radiator Covers

Where radiator covers are used, they have three distinct advantages that should be remembered:

1. They keep the engine and radiator warm,
2. They make starting easier, and
3. They save the storage battery to a marked extent.

The Thermostat

As an aid to regulation of the temperature of the cooling water with increase in thermal efficiency and reduced carbon deposits, the thermostat is a valuable adjunct in a cooling system

This device prevents free circulation of the cooling water through the cylinder cooling jackets until the temperature of the walls has reached the desired temperature for which the thermostat is set. Thus the walls and the cylinder heat can be kept at a sufficiently high temperature to aid in the complete vaporization and burning of the gasoline.

Automatic Radiator Shutters

Automatic radiator shutters are also used to serve this same purpose. These have the added advantage in maintaining a relatively uniform temperature in the air passing to the carburetor.

With a thermostatic control it is obvious that in certain instances the water passage might be so reduced that the air passing under the hood to the carburetor would take up relatively little heat, hence the temperature of the mixture might suffer a decided drop.

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